OPTIMIZATION AND CHARACTERIZATION OF MELAMINE UREA FORMALDEHYDE (MUF) BASED ADHESIVE USING NATURAL FILLERS FOR PLYWOOD

ONG HUEI RUEY

Thesis submitted fulfilment of the requirements for the award of the degree of Master of Engineering (Chemical)

Faculty of Chemical and Natural Resources Engineering
UNIVERSITI MALAYSIA PAHANG

September 2012

ABSTRACT

In this research, Palm Kernel Meal (PKM) and Palm Shell (PS) were studied as a filler for wood adhesive formulation and compared with present industrial filler (IF), wheat flour. Melamine Urea Formaldehyde (MUF) resin was selected as the resin for formulating the wood adhesive. The effects of natural filler on shear strength and formaldehyde emission of plywood were studied. The response surface methodology (RSM) was used to identify the optimum hot press temperature and press time for plywood process. The experimental results showed that the optimum hot press temperature and time of PKM, IF and PS were 129.5 ^{o}C; 133.7 ^{o}C; 130.7 ^{o}C and 170 sec; 159 sec; 186 sec respectively. The physico-chemical interaction between veneer and adhesive was investigated using Fourier Transform Infrared Spectroscopy (FTIR) technique. The FTIR spectrum of PKM showed blue shift which indicated that the functional groups (such as C=O, -OH and NH) become more free in the heat treatment samples. In the PKM-MUF blend bonding interactions, red shift occurred on C=O and N-H groups were observed. Red shift of C=O and N-H groups stretching in PKM-MUF-Wood blend was observed which suggests the interaction of these functional groups occur through hydrogen bonding. In addition, PKM-Wood-MUF with different amount of PKM, the bonding interaction between C=O (PKM) with O-H and N-H groups effectively involved more as the amount of PKM increase. Plywood bonded with PKM exhibited the highest shear strength comparitively with others. The formaldehdye emission of plywood bonded with PS was higher than PKM and IF respectively. At 13 % PKM concentration shows maximum shear strength. Experimental results showed that formaldehyde emission was minimum (environmental standard) at 18 % of PKM. This research concluded that, PKM based MUF adhesive resins exhibited potential application in production of plywood in Malaysia.

ABSTRAK

Dalam kajian ini, isirong sawit serbuk (PKM) dan tempurung kelapa sawit serbuk (PS) telah dikaji sebagai pengisi untuk penggubalan pelekat kayu dan berbanding dengan pengisi sekarang guna di industri (IF). Melamine Urea Formaldehyde resin (MUF) telah dipilih sebagai resin untuk merumuskan pelekat kayu. Kesan pengisi semulajadi pada kekuatan ricih dan pelepasan formaldehid papan lapis telah dikaji. Kaedah respons permukaan (RSM) telah digunakan untuk mengenal pasti suhu penekan panas dan penekan masa optimum untuk proses papan lapis. Keputusan pengajiaan menunjukkan bahawa optimum suhu penekan panas dan masa PKM, IF dan PS adalah 129.5 ^{o}C; 133.7 ^{o}C; 130.7 ^{o}C dan 170 sec; 159 sec; 186 sec masing-masing. Interaksi fiziko-kimia antara venir dan pelekat telah dikaji dengan menggunakan Spektroskopi inframerah transformasi Fourier (FTIR) teknik. Spektrum FTIR PKM menunjukkan anjakan biru yang menunjukkan bahawa kumpulan berfungsi (seperti C=O,-OH dan NH) menjadi lebih bebas dalam sampel selepas rawatan haba. Dalam PKM-MUF ikatan interaksi campuran, anjakan merah berlaku pada C=O dan kumpulan NH telah dipatuhi. Anjakan merah C=O dan kumpulan NH menjadi regang dalam PKM-MUF-Kayu campuran yang mencadangkan interaksi kumpulan berfungsi ini berlaku melalui ikatan hidrogen. Di samping itu, PKM-Kayu-MUF dengan kepekatan PKM yang berbeza, interaksi ikatan antara C=O (PKM) dengan OH dan kumpulan NH yang berkesan melibatkan lebih dengan jumlah PKM meningkat. Papan lapis yang terikat dengan PKM mempamerkan kekuatan ricih tertinggi berbanding dengan lain-lain. Pelepasan formaldehdye papan lapis yang terikat dengan PS adalah lebih tinggi daripada PKM dan IF. Pada 13 % PKM menunjukkan kekuatan ricih maksimum.Keputusan penyelidik menunjukkan bahawa pelepasan formaldehid adalah minimum (standard alam sekitar) pada 18 % daripada PKM. Kajian ini menyimpulkan bahawa, PKM berasaskan perekat resin MUF mempamirkan potensi dalam pengeluaran papan lapis di Malaysia.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

C	Formaldehyde concentration of test pieces
A_d	Absorbance of a sample solution
A_b	Absorbance of blank test
F	Inclination of calibration curve
x_1	Temperature
x_2	Pressing Time
x_3	PKM, PS, IF
Y_1	Shear Strength
Y_2	Formaldehyde Emission

LIST OF ABBREVIATIONS

ABES	Automated bonding evaluation system
ANOVA	Analysis of variance
BWT	Boiling water test
CA	Curing agent
CF	CNSL-formaldehyde
CNSL	Cashew nut shell liquid
CP	Crude protein
CPF	Control phenol formaldehyde
CV	Coefficient of variation
DKL	Demethylated kraft lignin
ECH	Epichlorohydrin
EFB	Empty fruit bunches
EVA	Ethylene vinyl acetate
F	Formalin
FLEC	Field and laboratory emission cell
FTIR	Fourier Transform Infrared Red
GA	Glutaraldehyde
GO	Glyoxal
IARC	International Agency for Research
IB	Internal bond strength
IF	Industrial wheat flour
JAS	Japanese Agriculture Standard
LPF	Lignin phenol formaldehyde

MA	Maleic anhydride
MDI	Diphenylmethane-4.4-discocyanate
MF	Melamine Formaldehyde
MOE	Modulus of elasticity
MOR	Modulus of rupture
MSPI	MA-modified SPI
MUF	Melamine Urea Formaldehyde
NaOH	Sodium hydroxide
NMR	Nuclear magnatic resonance
OSB	Oriented strandboard
PEI	Polyethylenimine
PET	Polyethylene terephthalate
PF	Phenol Formaldehyde
PFO	Phenol formaldehyde oligomer
PKC	Palm kernel cake
PKM	Palm kernel meal
PKS	Palm kernel shell
p-MDI	Polymeric methylene biphenyl diisocyanate oligomer
POME	Palm oil mill effluent
PPF	Palm press fiber
PRF	Phenol Resorcinol Formaldehyde
PS	Palm shell
PTF	Phenol tannin formaldehyde
PU	Polyurethane
PUF	Phenol urea formaldehyde resin

PUR	Polyurethane powder
PVAc	Polyvinyl acetate
PVOH	Polyvinyl alcohol
RF	Resorcinol Formaldehyde
RSM	Response Surface Methodology
SBR	Styrene butadiene rubber
SC	Sludge cake
SEM	Scanning Electron Microscope
SF	Soy flour
SPI	Soy protein isolate
SPI-K	SPI-kymene
SYP	Southern yellow pine
U_1	$Urea_1$
U_2	$Urea_2$
UF	Urea Formaldehyde
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

In this chapter, information about wood adhesive, resin and filler was provided. Apart from that, formaldehyde emission issue and bonding interaction of the adhesive were also discussed. In wood adhesive section, knowledge about wood adhesive was provided. The types of resin, background of filler, formaldehyde emission issue and bonding interaction will be discussed further in section 1.2, 1.3, 1.4 and 1.5 respectively. Research objective, research problem statement, research scope and rationale and significant will be proposed in section 1.6, 1.7, 1.8 and 1.9 respectively.

1.1 Wood Adhesive

Malaysia is one of the largest ten wood suppliers of wood-based products in the world region, especially to Europe, Japan, Taiwan, Singapore and Middle East. Malaysia is the leader of production and export of tropics wood log and main export country in tropics plywood, veneer and wood mold. Total exports of wood-based products from Malaysia amounted to RM14.89 billion in 2011(Malaysian Timber Board Industry, 2011). Wood industry exports in Malaysia rised nearly 40 % when compared to the exports 10 years ago. Other than that, total plywood exports from Malaysia amounted to RM3.83 billion in 2011 (Malaysian Timber Board Industry, 2011). Most of the plywood adhesive is formaldehyde based adhesive which is not environmental friendly because formaldehyde is a human carcinogen (International Agency for Research on Cancer, 2004). Plywood export to Europe and US was reduced due to the environmental issues. As the wood-based product is an important international player in the global market, so the quality of timber and timber products uphold and supply must be consistent.

The statistics showed that Malaysia has a wide range of market of wood industry. The important material for this industry is adhesive used for wood products production. During the last decades, there were many researches and development in wood-based industry and adhesive industry which have shown successful result. On the other hand, many industrial requirements still need noticeable developments in this area. Adhesives play a central role in wood-based panel production (Pizzi, 1994). The bonding quality and properties of the wood-based panel determined mainly by the adhesive types and quality. Development in wood-based panel is always linked to the development in adhesives and resins.

Wood adhesives are polymeric materials that are capable of interacting physically or chemically, or both, with the surface of wood in such a manner that stresses are transferred between bonded materials. Adhesives must be applied in the form of liquid, to spread over and wet the surface of the wood. Adhesive pre-polymers can be applied directly if they are liquids or can be applied as solutions, usually in water solutions. They are widely classed as either synthetic or natural as shown in Table 1.1 (Sellers, 1998). Adhesives are basically compounded by resin, filler and hardener. Therefore, resin and filler will be discussed in section 1.2 and 1.3 respectively.

Table 1.1: Classification of wood adhesives

Class	Resin type	Typical adhesive system
Synthetic		
Thermosetting	Amino	Urea-formaldehyde (UF) Melamine-formaldehyde (MF) Melamine-urea-formaldehyde (MUF)
	Phenolic	Phenol-formaldehyde (PF) Resorcinol-formaldehyde (RF) Phenol-resorcinol-formaldehyde (PRF)
	Isocyanate	Diphenylmethane-4.4-discocyanate (MDI)
	Epoxy	Bisphenol A-based epoxy resins
	Elastomeric	Styrene butadiene rubber (SBR)
Thermoplastic	Vinyl	Polyvinyl acetate (PVAc) Polyvinyl alcohol (PVA)
	Hot-melts	Ethylene vinyl acetate (EVA)
Natural		
	Protein	Casein Soybean Blood Animal

(Source: Seller, 1998)

1.2 Resin

Resin can be classified into two major classes which are synthetic resin and natural resin. According to Seller (1998), there are various types of resin such as amino, phenolic, isocyanate, epoxy, elastomeric, vinyl and hot-melts resin. The famous type of resin that is applied in the plywood industry is amino and phenolic resin. Therefore, the production of amino types resin and phenolic type resin especially PF, MF, UF and MUF will be briefly explained in the section 1.2.1; 1.2.2; 1.2.3 and 1.2.4 respectively.

1.2.1 Production of PF resin

The main material used to produce PF resin were phenol, sodium hydroxide and formaldehyde. The phenol was mixed with 40 % sodium hydroxide solution and formaldehyde in a three-neck reactor equipped with a stirrer, a thermometer and a reflux condenser. Stir the solution for 20 min at 40 ^{o}C. Then the reaction mixture was heated to reflux (90 ^{o}C) over a period of 30 min at constant temperature. Formaldehyde and the appropriate amount of distilled water were added to the reactor. The temperature was kept at 85 ^{o}C until the Gardner-Holdt viscosity (measured at 20 ^{o}C) of the resin was reached between 300 - 500 mPa.s. The resin was cooled to 30-40 ^{o}C (Fan et al., 2009).

1.2.2 Production of MF resin

Initially, Melamine, Formalin (37 %) and water are mixed in a three-neck reactor equipped with a stirrer, a thermometer and a reflux condenser. The pH of the mixture was adjusted to 9.0 with 20 % sodium hydroxide solution and refluxed at temperature 100 ^{o}C. The melamine was added for final formaldehyde to melamine mole ratio of 2:1. The temperature of the mixture was dropped to 90 ^{o}C when the melamine was added. After the melamine was completely dissolved in the mixture, it was heated 10 min and then cooled to room temperature. Final miscibility was about water to resin ratio of 1:1 at 25 ^{o}C (US patent 3470134, 1969).

1.2.3 Production of UF resin

The one-step process as described by Barminas and Osemeahon (2007) was used in the preparation of trimethylol urea by reacting one mole of urea with three moles of 37 % (w/v) formaldehyde by using sodium dihydrogen phosphate (Chen et al., 2001). The pH of the solution was adjusted to 6 using 0.5 M H_2SO_4 and 1.0 M NaOH solutions. The solution was heated in thermostatically controlled water bath at 70 ^{o}C. The reaction was allowed for 2 hours after which the sample was removed and kept at 30 ^{o}C (Osemeahon et al., 2007).

1.2.4 Production of MUF resin

The main materials used to produce MUF resin were formaldehyde, melamine, urea and sorbitol as additive. The MUF resin synthesis process is carried out in three reaction stages. In the first stage, formalin (37 %) is poured into a three-necked flask, followed by melamine, urea1 and sorbitol. The speed for the rotator is set to 7. The initial temperature of the mixture is 65 °C. Several drops of sodium hydroxide ($NaOH$) with 40 wt% concentration of solution are added to adjust the pH of the mixture to 8.5-9.0. Then, the pH of the mixture is monitored. In the second stage of the resin synthesis, the temperature of the mixture is raised to 80 ^{o}C. Refluxing is continued until the end point is reached. The end point can be determined by dropping the mixture in water at 30 ^{o}C for every 5 minutes. If the mixture droplet is diluted in the water without any trace, it means the end point has not yet been reached. Upon achieving the end point, the pH of the mixture is adjusted to 8.5-9.0 by adding $NaOH$ solution. Finally in stage three of resin synthesis, urea2 is added upon achieving 60 ^{o}C. The resin was cooled down to an ambient temperature and transferred to a plastic container for further testing (Bono et al., 2003, Bono et al., 2006, Bono et al., 2007 and Bono et al., 2008).

1.3 Background of Filler

Generally, adhesive is made from a combination of 5 main compositions. These include resin, extender, filler, pigment and solute. Each of composition gives different contribution in the formulation for producing the desired adhesive. In the Table 1.2 below, application of each composition in adhesive is summarized. Each type of composition is purposed to make sure adhesive can be adopted for various applications (Jackson, 1976).

Table 1.2: Composition material in adhesive

Material	Function
Resins	Main and most important component in adhesive where it gives the characteristics of adhesive.
Filler	Chemical material that is added to adhesive to decrease the adhesive cost and lower the resins dissipated into the wood. It also fills up tiny hole on the board surface to avoid weak bonding.
Extender	Glucose source, which become gelatin under alkaline condition, where gelatinized starch gives sticky characteristic and increase viscosity of adhesive. Besides that, extender is also used to control the adhesive when it is use.
Pigment	Chemical agent, which gives color for adhesive.
Solute	Chemical agent, which is added to the adhesive to change viscosity and adhesive gelation.

(Source: Jackson, 1976)

Filler used to lower the resins dissipated into the wood as well as to control the production cost. It also fills up the tiny hole on the board surface to avoid weak bonding. Therefore, the adhesive that is used in the industries consists of resin,hardener and filler (Pizzi, 1994; Ebewele and Koutsky, 1986). However, the shear strength performance of adhesive with filler was weak than without. In order to overcome these phenomena, there are many other types of fillers that are proposed such as wheat flour, soybean, tapioca flour, corn starch flour and so on.

In Malaysia, wood industry uses filler to increase the solid content and reduce the production cost. One of Malaysia's largest wood producers, Shin Yang Chemical Sdn. Bhd. Used wheat flour (industrial flour) as the filler for wood product. The reason of Shin Yang Chemical choosing wheat flour as their filler is due to the protein content of the wheat flour. Wheat flour consists of a large amount of protein and this protein content would enhance the bonding formation between the adhesive and wood surface. However, the price of wheat flour is high and it is the edible one which can used in food sector. Therefore, in this research, Palm Kernel Meal (PKM) and Palm Shell (PS) were proposed as the substitution for the wheat flour. The reason to choose PKM and PS as the filler is due to Malaysia is the world second largest export in palm oil. Malaysia has plenty of palm oil mills, where, PKM and PS was the by-product of the palm oil mill. Besides that, the chemical properties and content of PKM have the similarity with industrial wheat flour. The major component in the PKM is the protein compound. PKM, PS and Wheat flour will be discussed further in section 1.3.1; 1.3.2 and 1.3.3 respectively.

1.3.1 Palm Kernel Meal (PKM)

Palm oil is one of the major agro-industries in Malaysia, but the by-product contribute from the palm oil mill include the empty fruit bunches (EFB), palm press fiber (PPF), palm kernel cake (PKC), palm kernel shell (PKS), sludge cake (SC) and palm oil mill effluent (POME). Only EFB, PPF, PKS and POME appear in large quantities and are considered as wastes. The others can be sold for animal feed or fertilizer. Average percentage of the FFB composition found from the survey (28 % EFB, 12 % PPF and 8 % PKS) (Prasetsan et al., 1996). The solid wastes from palm oil mills are classified into shell (3.25 %), fiber (11.79 %), empty fruit bunch (51.36 %), and kernel (33.6 %). Shell, fiber and empty fruit bunch mainly consist of lignin, cellulose and hemi-cellulose. Thermo-chemical conversion, especially pyrolysis, of these three chemicals produce a liquid mixture of several valuable hydrocarbons (e.g. alcohols, aldehydes, ketones, carboxylic acids, phenol and its derivatives) (Yan et al., 2005). The chemical properties of PKM was shown in Table 1.3.

PKM is a by-product of palm kernel oil extraction from the nut of the palm tree, Elaeisguineensis (Perez et al., 2000). Palm Kernel Meal (PKM) contains biomaterials such as protein, cellulose and organic acids. The transformation of this by-product into new and non-conventional source of proteins is of great interest because of it crude protein content (≈ 14 - 20 %) and the resourcefulness of this material (Iluyemi et al., 2006) in Malaysia.

PKM can be extracted and purified to be used as animal feed supplement in animal feed industry. It supplied valuable dietary sources of protein, energy and fiber (Iluyemi et al., 2006). According to Boateng et al. (2008), PKM also has been found that to reduce the cost of animal’s diet. Besides that, PKM contains proteins were well known to be used as cattle feed concentrates in dairy cows to increase milk fat. However, PKM is more suitable consumed by ruminants (cattle, sheep) but limited to use as feedstuff for monogastric animals such like chicken, swine, fish and others. It is because PKM contains high fiber (cellulose, hemicellulose), low digestibility.

According to Malaysian Palm Oil Board (2008), Malaysia produced around 2,358,732 tons of by-products Palm Kernel Meal (PKM) from palm oil (15,823,745 tons). Malaysia has been the largest Palm Kernel Meal (PKM) exporter in the world, the current global leader in the oil palm industry, with the European Union countries importing more than 85 % of Malaysian Palm Kernel Meal (PKM) annually with low price. The other importers are the Netherlands, United Kingdom, Germany, Ireland, and Asian countries like South Korea and Japan (Subbarao et al., 2008). Palm Kernel Meal (PKM) is obtained through either mechanical (expeller) or solvent process. The global production of Palm Kernel Meal (PKM) was ever increasing due to the tremendous growth of the oil palm industry in many parts of Asia and Africa. Therefore, Palm

Kernel Meal (PKM) is a readily and suitable raw material to be used for plant protein source.

Table 1.3: Chemical Properties of PKM

Fraction	**Composition**
Dry matter, %	94
Crude protein, %	14 – 21
Crude fibre, %	21 -23
Ash, %	3 – 6
Gross energy, Kcal/kg	4,998

(Sources: Boateng et al., 2008)

1.3.2 Palm Shell (PS)

There was 3.25 % of palm shell produced from the palm oil mill and treated as waste. Shell mainly consists of lignin, cellulose, and hemi-cellulose and trace amount of protein (≈0 %) (Yan et al, 2005) (Islam et al, 1999). PS was the most difficult waste to decompose. The shell size was uniform and not as bulky as the EFB. They were usually left unused in the factory or disposed of in the land-fill. In terms of energy, PS was an energy intensive substance. Local industries that require process heat (or steam) generally have furnaces (or boilers) designed for firewood or fuel oil. However, substantial modification of the furnaces is needed if the conventional fuel were to be replaced by PS. Therefore, many factories are still reluctant to use PS as fuel unless they were economically forced to do so.

There is a possibility that the PS can be used for activated carbon productions (Daud and Hamid, 1990) (Hamid et. al., 1992) or charcoal (Kirkaldy and Sutanto, 1976). PKS contains 20.3 % of fixed carbon and is physically similar to the coconut shell, which has been used to produce the activated carbon successfully. It was anticipated that the stringent environment control measures will increase the demand for activated carbon in the future. It is possible that activated carbon can be applied for the decolorization of the unacceptably dark-colored effluent of the palm oil mills (Prasetsan et al., 1996). The chemical properties of PS was shown in Table 1.4.

Table 1.4: Chemical Properties of PS

Fraction	**Composition**
Hemicellulose, %	≈22.7
Cellulose, %	≈20.8
Lignin, %	≈50.7
Crude protein, %	≈ 0

(Sources: Aziz et al, 2012)

1.3.3 Industrial Wheat flour (IF)

Wheat was the leading cereal grain produced in the world, with a production of nearly 600 million metric tons (MMT) in 2000 (USDA/NASS, 2001). It is used worldwide for food (67 %), feed (20 %), and seed (7 %). The wet-milling of wheat flour to produce starch and vital gluten as the major co-products has been reported to account for 6 % of total production (Oleson, 1994). Hard and soft wheat flours with a high protein content (>11 %) are preferred in wet-milling to co-produce vital wheat gluten and wheat starch (Sayaslan, 2004).

There are many types of wheat flour, which differ in characteristics according to factors, such as the variety of wheat, growing conditions, planting and harvesting times. Wheat flour is sold in three main forms – wholemeal, brown or white.

Gluten-free flour complies with the international gluten-free standard and is most commonly used in products specifically manufactured for people with coeliac disease. It is made from wheat flour, which has had most of the proteins, including the gluten, removed. Malted wheat grain flour is brown or wholemeal flour with added malted grains. Plain flour contains 10 % protein and is suitable for a variety of uses such as biscuits and sauces. Strong flour contains a maximum of 17 % protein and is used for yeast doughs and for flaky, puff and choux pastry. Weak/soft flour contains 8 % protein and is suitable for cakes. Wheat germ flour is brown flour, which contains at least 10% added wheat germ (the embryo of the wheat seed which is usually discarded when wheat is milled to white flour) (British Nutrition Foundation, 2004). Besides that, industrial wheat flour as the by-product of the wheat flour milling industry, the protein content with less than 8 % (Perry, 1944). The chemical properties of IF was shown in Table 1.5.

Table 1.5: Chemical Properties of IF

Fraction	**Composition**
Crude protein, %	≈7.11
Ash, %	≈0.36
Wet gluten, %	≈2.05
Dry gluten, %	≈0.70

(Sources: Chiang et al, 2006)

Apart from that, environmental and health issue will be discussed in the following section. Besides that, in section 1.5 will discuss bonding interaction of adhesive and wood.

1.4 Formaldehyde emission issue

Formaldehyde, one of the key ingredients in currently used wood adhesives such as PF, MF, UF and MUF. The wood based panels and flooring materials have gained great attention from the wood industries and the general public. Currently, inexpensive formaldehyde based thermosetting resin such as phenol formaldehyde, urea formaldehyde, melamine formaldehyde and melamine urea formaldehyde adhesive was commercially used in wood industry. However, formaldehyde has become well known as a toxic air contaminant and carcinogenic agent. World Health Organization (WHO) intergovernmental agency, International Agency for Research on Cancer (IARC) reclassified formaldehyde from “probably carcinogenic to humans (Group 2A)” to “carcinogenic to humans (Group 1)” in June 2004 (IARC, 2004).

1.5 Bonding interaction

Plywood shear strength performance evaluation was based on Japanese Agriculture Standard (JAS, 2003). Automated bonding evaluation system (ABES) was the common method to determine the shear strength of the adhesive and testing for the bond strength development during the curing time. There is many researches done to determine the bonding interaction of adhesive. Several instruments were proposed in investigating the bonding interaction such as 13^{C} Nuclear magnetic resonance (13^{C} NMR), Fourier Transform Infrared Red (FTIR) spectroscopy and other (khan et al., 2004; Soto et al., 2005; Liu and Li, 2006; Mansouri and Pizzi, 2007; Mishra and Sinha, 2010; Li et al., 2010; Kong et al., 2011). However, there are limited researches done in analyses the bonding interaction between resin, filler and plywood. Therefore in this study, we proposed Fourier Transform Infrared Red (FTIR) spectroscopy and Scanning Electron Microscope technique in bonding interaction study.

Hence, objective of this research is to study the suitability of Palm Kernel Meal as the filler. Besides that, comparison of the adoption of Palm Kernel Meal (PKM) with currently used filler such as wheat flour and palm shell (PS) in Melamine Urea Formaldehyde (MUF) resin based adhesive production. The comparison of effect is bonding strength (shear strength) and formaldehyde emission of plywood bonded with adhesive with a different type of filler. The reason of choosing PKM is due to the similar characteristic with industry wheat flour. The main component in the PKM is protein. Apart from that, FTIR and SEM techniques were used to investigate the bonding interaction between MUF resin, filler and wood.